

1994014697

58-12

186150

THE FIRST FLIGHT OF THE QUESTS GAS PAYLOAD, G-521

Darrin Gates, Electrical Systems Engineer,
Bristol Aerospace, Winnipeg, Manitoba

N 9 4 - 1 9 1 7 0

442480

ABSTRACT

An overview of all of the phases of the QUESTS Get Away Special project is presented in this paper. Details from the early phases of the project; design, manufacture and test, through to the first flight results are provided. The handling of safety issues, payload capabilities, the experiment complement, payload integration and de-integration and interfacing with NASA is also discussed.

INTRODUCTION

The QUESTS (Queen's University Experiment aboard the Space Transportation System) project originally started as a Canadian Space Agency (C.S.A.) competition to come up with a microgravity materials processing experiment. Prof. Reg. Smith (Queen's University) won the competition and was tasked to design the furnaces and to define the experiments that would fly on a Shuttle based Get Away Special (GAS) payload. Bristol Aerospace was then contracted by the C.S.A. to design, manufacture, test and integrate the GAS payload to accommodate Queen's University science and to satisfy all NASA safety requirements. During the design phase it was realized that more furnaces could be accommodated. This led to the invitation of Dr. Kedar Tandon at the University of Manitoba to participate in this GAS project.

DESIGN, MANUFACTURE AND TEST

The QUESTS payload hardware and software were designed to act as a flexible platform for material experimentation and research in a microgravity environment. The payload was designed to handle the initial experimenter requirements and to accommodate future science as well. The philosophy of the design approach included the following considerations;

- a modular hardware design for easy removal and replacement of experiments and subsystems,
- design of flexible controller software that would allow for simple experiment parameter changes,
- large contingencies in the available stored energy to handle future experimentation.

NASA safety requirements and proper material selection were of foremost concern during design and manufacture. Wire and fuse sizes were selected such that the wire temperature would remain below vacuum rated limits under maximum current conditions. A structural analysis was performed to ensure payload integrity during launch and landing loads. Maximum furnace temperatures during thermal runaway conditions were determined to ensure compatibility with payload materials. Pressure of the heatsink container was determined for maximum thermal input conditions.

Flight environment concerns were also addressed during payload design and manufacture. Environmental testing activities included;

- vibration (3-axis, 15g on components, 3g on the entire payload),
- temperature (-40 to +85°C),
- full flight simulation test (real time operation simulating the actual flight operations).

SAFETY

All three phases of the NASA safety document submissions were without any major problems. The Preliminary Safety Data Package (SDP) was submitted early during the design of QUESTS. Preliminary parts lists, drawings and test results were supplied in this SDP. Early hazard assessments were made and controls were proposed.

During manufacture as some of the safety concerns were addressed, the Final SDP was submitted. The Final SDP included more detailed parts/material lists and drawings that reflected the as built payload. Testing results were also included in the Final SDP. Hazard assessments and controls were also refined. After this submission NASA requested that an Energy Containment Analysis be performed. The containment analysis, in QUESTS case, was a detailed thermal analysis that showed all of the stored energy in the battery system could be contained within the payload structure and support systems without raising the temperature to hazardous levels. This analysis simplified the safety documentation. A number of the hazard assessments and controls could be removed, after the analysis results showed that the hazards were no longer probable.

The Phase III SDP was submitted after payload testing was completed. All of the To Be Determined (TBD's) were answered and the documentation reflected the actual as built, as tested QUESTS GAS payload. No outstanding items were in the Phase III SDP, and it was this document that was used at the Kennedy Space Center (KSC) during integration to approve the payload for flight.

PAYLOAD CAPABILITIES

The QUESTS payload is capable of carrying 12 isothermal diffusion and 3 gradient crystal growth/directional solidification material processing experiments. Each furnace is capable of temperatures of up to 1000°C.

Each isothermal furnace contains 1 winding and an integral motor/quench block assembly for sample insertion, extraction and cooling (Figure 1).

Each gradient furnace contains 3 windings and the stationary sample is internally fastened to an aluminum foam/paraffin wax heatsink (Figure 2). The heatsink assembly removes heat from the sample to create a temperature gradient.

The payload controller and flight software provide the timing, experiment control, data acquisition and storage functions for QUESTS. A flexible PID algorithm is used to control the furnace temperatures. Time and temperature profiles for each experiment are individually programmable. Experiment temperatures are saved once per minute along with the diagnostics. A 1 Mbyte memory cartridge is used to store experiment temperature and diagnostic data. Expansion of the memory cartridge to 4 Mbytes is being examined for future flights.

Associated electronics provide the interface to thermocouples, power windings, stepper motors, diagnostic sensors, power system and ground support equipment.

Power for the payload is provided by 2 packs of silver-zinc cells, capable of about 2.2 kWatt-hours.

Diagnostic data parameters are measured and saved periodically during the flight. Parameters measured include: acceleration, payload temperatures, pressures, bus voltages and current. These parameters are saved to the memory cartridge along with date, time, status flags and messages for postflight processing.

Low level accelerometers ($\pm 10\text{mg}$ full scale) are used to measure the microgravity environment. The readings are filtered above 0.6 Hz and can resolve to $1.2 \mu\text{g}$.

Ground support equipment hardware and PC-based software provide tools to test experiment concepts and verify payload operation prior to flight.

A picture of the QUESTS GAS payload is shown in Figure 3.

EXPERIMENTS

The experiment complement on the first flight of QUESTS was made up of directional solidification and diffusion experiments. Professor Reg Smith and Steve Goodman (Queen's University, Kingston) had 14 samples and Kedar Tandon (University of Manitoba) had 1 sample. Table 1 provides a description for each of the experiments.

The results of the solidification of the Bi-BiMn eutectic at small growth rates will assist Queen's in the development of the theory of anomalous eutectic freezing. Previous work by Queen's and others suggest an anomalously low value for the interphase spacing when the eutectic is frozen slowly.

The University of Manitoba is studying the effect of microgravity on the segregation, phase morphology and the phase distribution of Al-38%(wt)Cu hypereutectic.

Queen's diffusion experiments are designed to measure diffusion coefficients for a number of alloy systems to provide data from which to further develop our understanding of the structure of liquids. The diffusion experiments include the materials; Pb, Au, Bi, Ag and Mn.

PAYLOAD INTEGRATION

Payload integration took place in June 1992, about 3 months before launch. The facilities on the Cape Canaveral Air Force Station (CCAF) were excellent and the GAS integration team was very helpful. Preparation of QUESTS for flight included the following activities;

- battery top-up charging (the batteries were fully charged prior to shipment),
- sample installation (the flight samples were hand carried by the experimenter to the integration facility),
- hardware securement (all fastening hardware was checked),
- payload operation (all systems were checked, verified in the flight configuration and given a GO status),

- NASA interface verification (payload operation using interface plate),
- installation into the flight canister,
- purge and leak checks.

FLIGHT CHARACTERISTICS

The QUESTS GAS payload flew on STS-47. The published flight characteristics for STS-47 are;

Launch	-	12 Sept. 1992, 10:23
Shuttle	-	Endeavour
Orbit	-	163 nm x 57° inclination
Attitude	-	gravity gradient
Landing	-	20 Sept. 1992, 8:53

The QUESTS payload flew on the GAS bridge assembly (Figure 4) and the final measured weight was exactly 200 lbs.

PAYLOAD DEINTEGRATION

The same facilities were used for deintegration as for integration. Deintegration took place in October 1992, about 1 month after the flight. Deintegration activities included;

- canister leak check (to verify integrity of the seal),
- payload removal from the flight canister,
- payload operation (to ensure functionality after the flight),
- data extraction (the memory cartridge with experiment and diagnostic data was downloaded to the PC),
- sample removal (all samples were removed and hand carried back to the scientist for processing).

FIRST FLIGHT RESULTS

All of the experiments on the first flight of the QUESTS payload operated as planned. The directional solidification flight samples have been analyzed and the results were good. Queen's eutectic samples showed no difference between the micro-g and ground based processing. This result was proposed by Queen's prior to flight and verified by KC-135 and drop tower processing. The University of Manitoba observed excellent long crystals in their sample processed on the shuttle. A more homogeneous mixture was obtained with no precipitates due to gravity.

A typical flight temperature profile for a gradient furnace is shown in Figure 5.

The diffusion samples have not been sectioned yet, therefore science results specific to these experiments are not available at this time.

Diagnostic data was extracted from the memory cartridge and analyzed on the PC. Temperatures inside the payload ranged from about 41°C steady state to about 85°C peak on a deck near one of the operating furnaces (Figure 6). The payload temperatures were higher than expected possibly due to the gravity gradient (tail pointed toward earth) attitude used for this flight. Discoloration of the external GAS can cloth and the yellowing of the GAS bridge assembly itself were other indications of the

extreme thermal environment experienced during the flight.

Filtered acceleration data indicated peaks of about 140 μg during experimentation. The acceleration data for each axis did exhibit offsets from zero-g during flight. Typical acceleration perturbations from these offsets were in the order of 50 μg (Figure 7).

CONCLUSIONS AND FUTURE ACTIVITIES

Payload operations were as planned. The scientists were pleased with the results of their experiments in the microgravity environment. The QUESTS GAS payload will be refurbished for re-flight with a new experiment complement. QUESTS 2 should be ready for flight about the middle of 1994.

Table 1 - QUESTS Experiment Complement

Expt Number	Furnace Type	Experiment Description	Times (minutes)
1	Gradient	Directional Solidification of Bi-MnBi (eutectic)	105
2	Gradient	Directional Solidification of Bi-MnBi (eutectic)	180
3	Gradient	Directional Solidification of Al-38% (wt) Cu (hypereutectic)	105
4	Isothermal	Diffusion of Pb-Au (363°C)	150
5	Isothermal	Diffusion of Bi-Ag (313°C)	120
6	Isothermal	Diffusion of Pb-Au (437°C)	120
7	Isothermal	Diffusion of Bi-Mn (313°C)	120
8	Isothermal	Diffusion of Pb-Au (538°C)	90
9	Isothermal	Diffusion of Pb-Ag (363°C)	90
10	Isothermal	Diffusion of Pb-Au (850°C)	60
11	Isothermal	Diffusion of Pb-Ag (517°C)	60
12	Isothermal	Diffusion of Bi-Ag (437°C)	60
13	Isothermal	Diffusion of Pb-Ag (850°C)	35
14	Isothermal	Diffusion of Bi-Ag (695°C)	30
15	Isothermal	Diffusion of Bi-Mn (695°C)	30

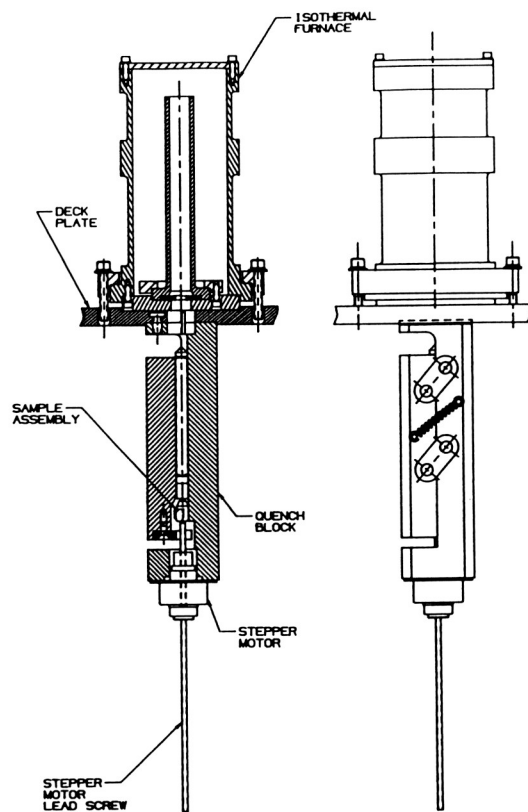


Figure 1 - Isothermal Furnace Assembly

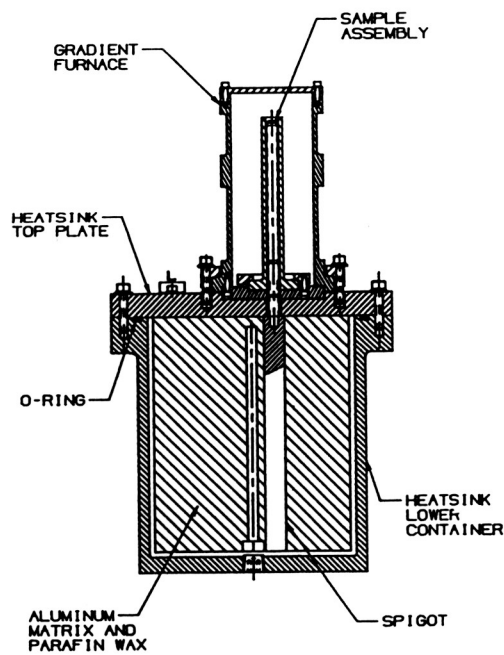


Figure 2 - Gradient Furnace - Heatsink Assembly

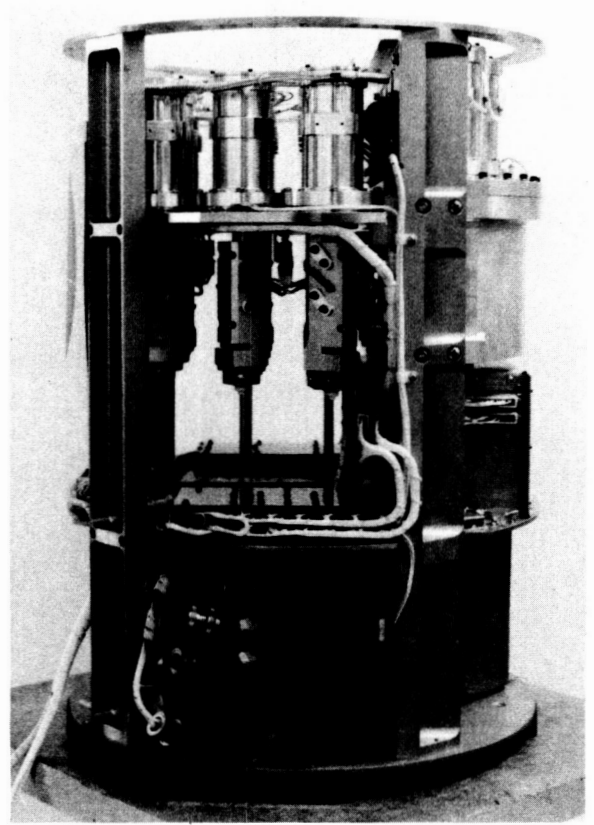
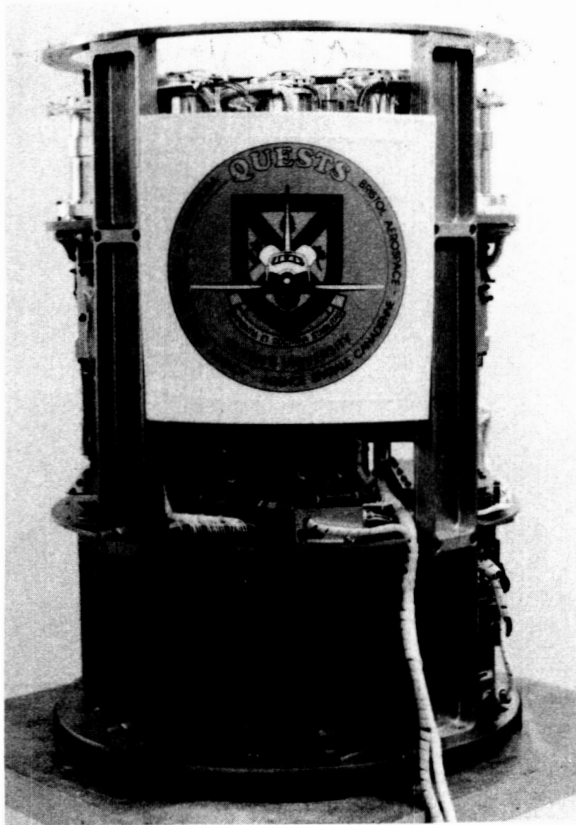


Figure 3 - QUESTS GAS Payload, 2 Views

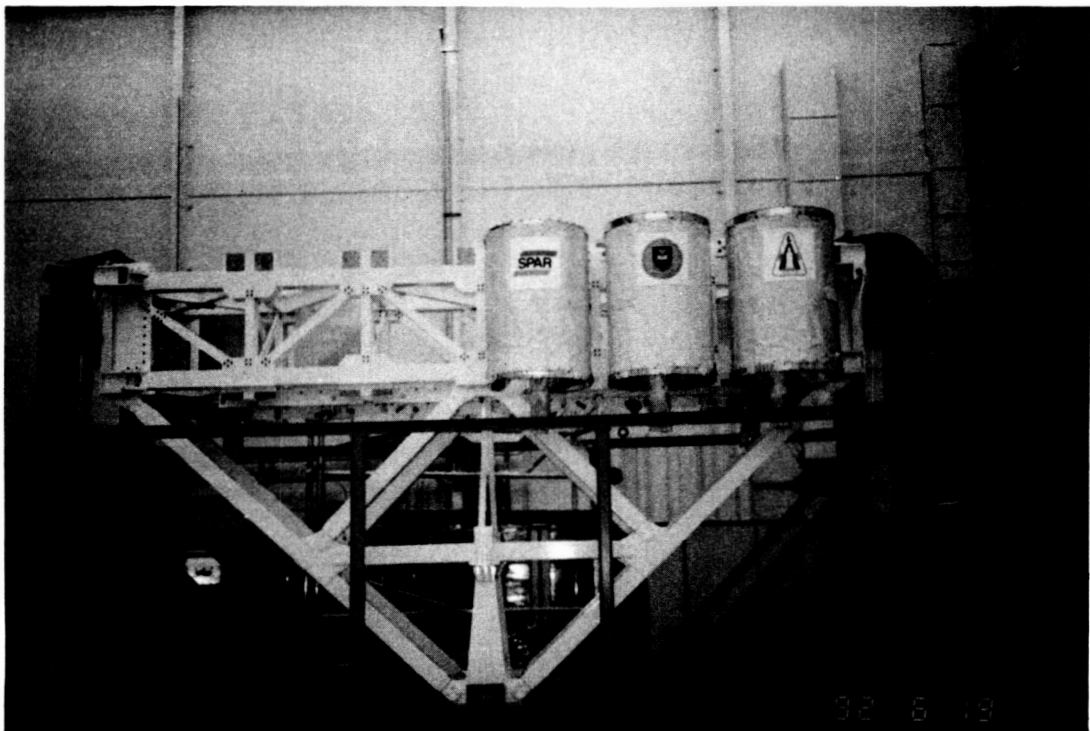


Figure 4 - QUESTS on the GAS Bridge Assembly

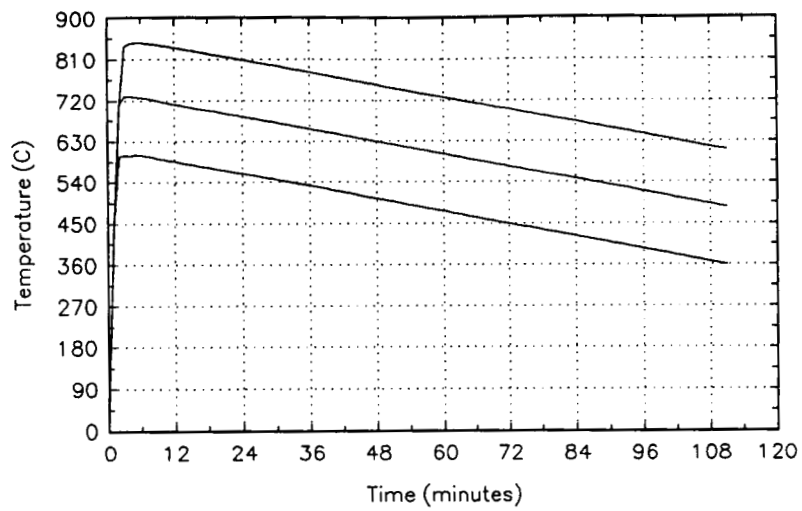


Figure 5 - Graph of Gradient Furnace Flight Temperatures

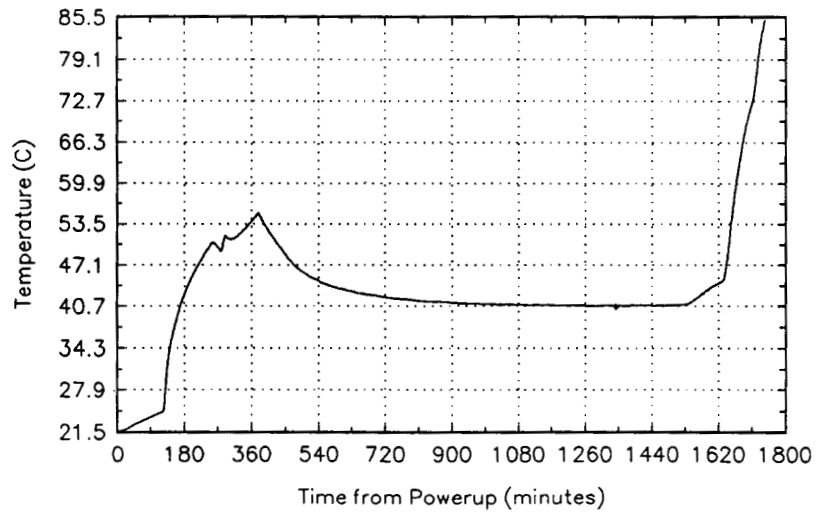


Figure 6 - Graph of Isothermal Furnace Deck Flight Temperature

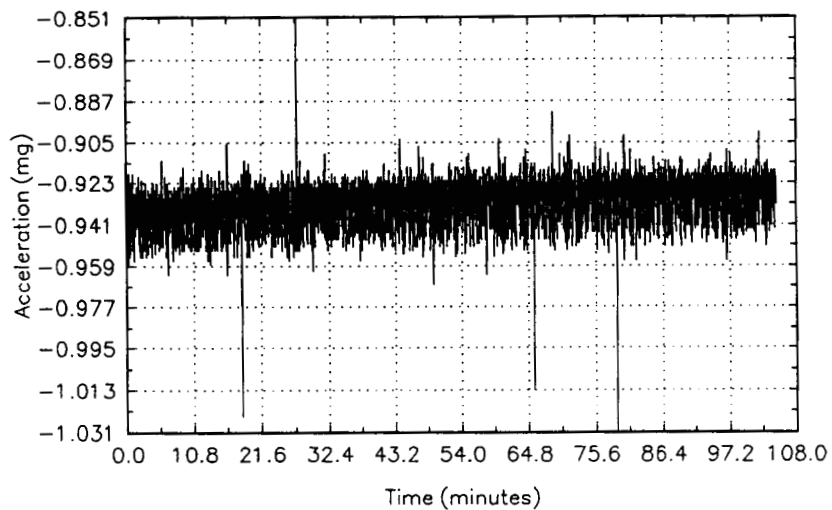


Figure 7 - Graph of Typical X-axis Acceleration During a Flight Experiment